Thermomechanical Treatment of Steels – A Real Disruptive Technology Since Decades

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The basic concept of thermomechanical treatment (TMT) or thermomechanical controlled processing (TMCP) is responsible for the development of many advanced steel grades with improved mechanical properties during the last 50 years. A retro-perspective view, an explanation of the most important influencing factors and a presentation of the enormous benefits for the costumer are given in this review. A sound knowledge on the synergism of recrystallization, precipitation, and transformation phenomena forms the basis to produce fine, homogeneous microstructures with improved properties. Starting from structural steels, improvements can be achieved with respect to higher strength and toughness values combined with better weldability and formability, mainly based on reduction of carbon content and finer grain sizes. The benefits in the application areas are described in detail. TMCP is not only used for flat products, but also for long products and forgings of different steel grades. Physical simulation and modeling contribute significantly to these developments, which also form the basis for computer-aided control or real-time online-models. In the next years, a complete shift to cyber physical systems (CPS) is predicted, which needs an aligned education effort.

1. Introduction

Structural steels or CMn low alloy steels were primarily used after the Second World War for most of our infrastructural goods, like bridges, cranes, houses, pipelines, and other engineering applications. Two ferritic–pearlitic steel grades, St37 and St52, dominated the European industry. The traditional ingot casting was replaced by continuous casting and hot-rolling became a very economic and well controlled processing route. In addition, there was an increasing demand for high strength steels with improved toughness and a better weldability. In the late sixties and seventies, materials engineering in US and UK drifted more and more into materials science and researcher created new ideas and invested new alloying systems and fundamental mechanisms. A better control of finishing rolling temperature at lower level led to finer homogenous distributions of microstructure with improved mechanical properties and a higher reliability for mechanical engineering applications. An improved understanding of recovery and recrystallization phenomena and how to increase the toughness behavior of steels were introduced in good textbooks.[1–8] The primary grain refinement was found by the recrystallization of austenite during hot deformation, which not only depends on temperature, but also on the degree of deformation during each rolling pass. This was the beginning of the implementation of thermomechanical treatment of steels in rolling mills. Precipitates of microalloying elements, like Ti, Nb, and V became important for the grain size control and the recrystallization kinetics. Parallel to these developments, low temperature treatment of the metastable austenite, socalled Ausforming, was applied to achieve high-strength low-alloy (HSLA) steels.

In the eighties and nineties, an enormous effort was put on the optimization of the amount of alloying elements and processing conditions. Additional microstructural modifications based on different cooling strategies have led to even higher strength levels at moderate toughness and multiphase steels were created for the automotive industry. Front runners at that time were the oil and gas industry by a rapid development of steel grades from X60 to X120 within three decades.[9]

In this review, the fundamentals on fine-grained structural steels, the most important mechanisms and parameters, as well as the benefits for the application in different important engineering fields will be brought back into our memories.

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